From *SIRTF* to *Stromatolites*

Infrared Surveys & the Biological Potential of Other Planetary Systems

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19 August 1999

Debris Disk Surveys & Astrobiology

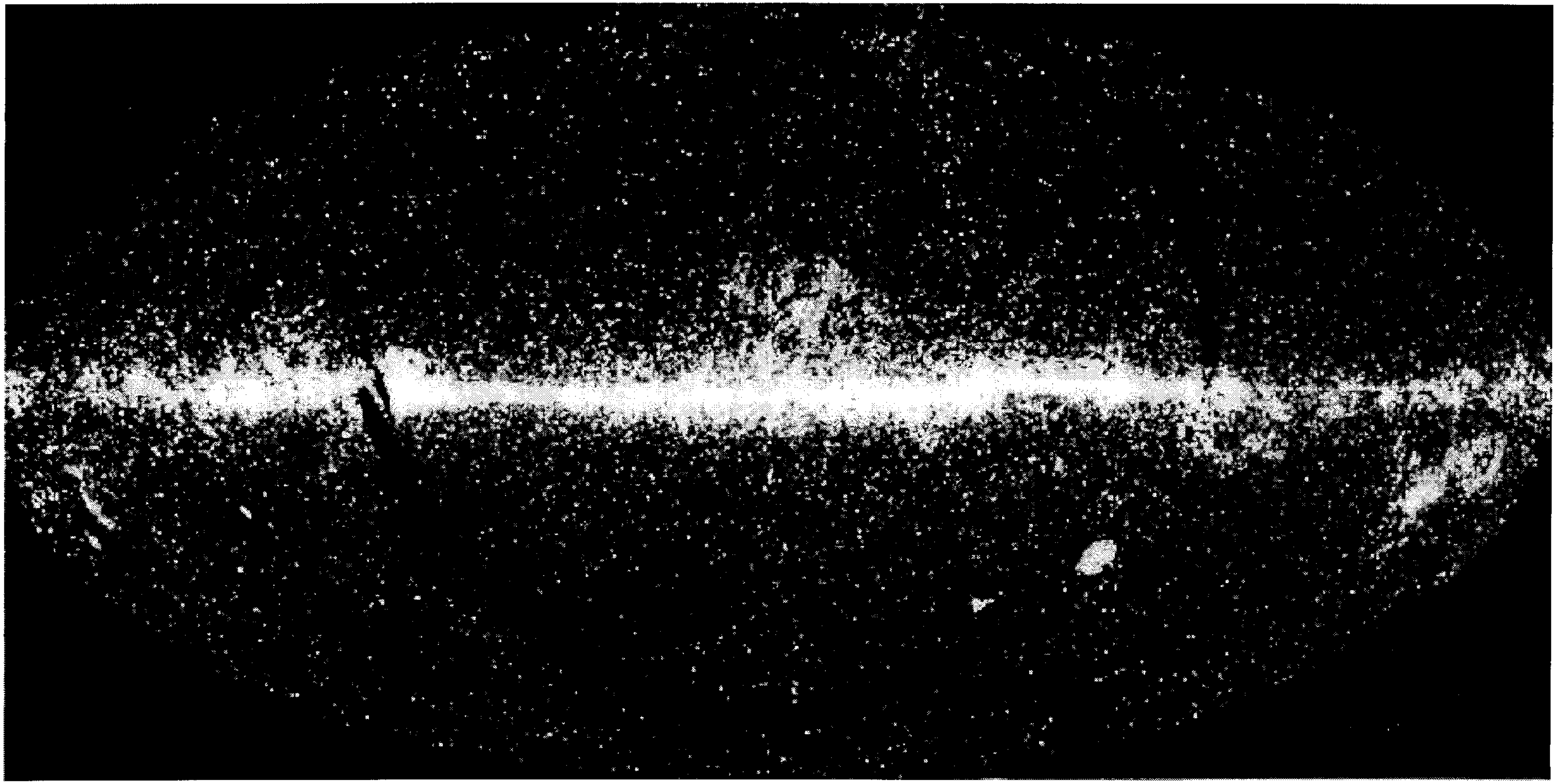
"To See a World in a Grain of Sand"

-- *William Blake*

Can the geometric and spectroscopic properties of a debris disk constrain planetary properties relevant to the existence of biospheres? **Perhaps**

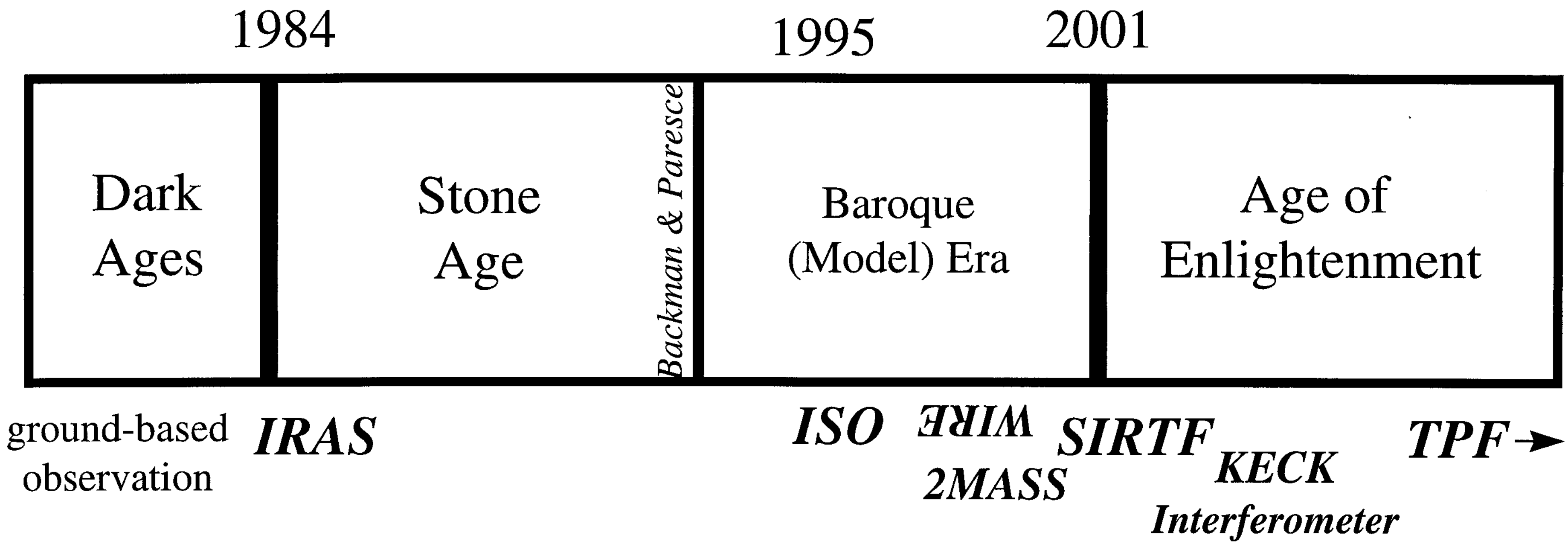
Can a debris disk affect the detection of Earth-like planets around a star? **Yes** (Beichmann 1998 SPIE 3350: 719)

Infrared Surveys in a New Light



IRAS Point Sources (courtesy IPAC)

Infrared Astrobiology



The Stone Age

Debris Disks around MS Stars → Planet-forming bodies (stones) → Planets → Life

Lifetime of circumstellar dust grains is much shorter than stellar ages, implying a reservoir of larger solid bodies presumed related to planet formation.

$$\tau = 700\, r^2\, a\, Q^{-1} L_*^{-1}\ yr$$

Q: What fraction of low-mass stars have circumstellar debris disks?

A: Perhaps ~10% at the detection threshold of *IRAS* (corresponding to several thousand times Solar System zodiacal)

Survey	Year	Observatory	Size	Spectral Type	Dust	Star Catalogs
Aumann et al.	1984	IRAS	1	A0		Vega
Aumann	**1985**	**IRAS**	**36**	**AFG**	**33%**	**Gliese/Woolley**
Gillett	1986	IRAS				
Sadakane & Nishida	1986	IRAS	4	A		
Backman & Gillett	**1987**	**IRAS**	**134**	**A**	**19%**	**Bright Star**
Walker & Wolstencroft	1988	IRAS		A-M		SAO
Stencel & Backman	**1991**	**IRAS**	**5706**	**B-M**	**7%**	**SAO**
Oudmaijer et al.	1994	IRAS		B-M		SAO
Mannings & Barlow	**1998**	**IRAS (FSC)**		**A-M**	**<37%**	**Michigan**
Moneti et al.	1998	ISO	7			Lindroos binaries
Abraham et al.	**1998**	**ISO**	**9**	**A**	**11%**	**UMa moving group (300 Myr)**
Gaidos	**1999**	**IRAS (FSC)**	**38**	**G0-K2**	**3%**	**young solar analogs (200-800 Myr)**
Habing et al.	**1999**	**ISO**	**22**	**A-K**		**(< 1 Gyr)**
Fajardo-Acosta	**1999**	**ISO**	**38**	**A-M**	**14%**	**Bright Star/Gliese**

The Baroque (Model) Era

Dust disk geometry → Planetary system architecture → Earth-like planets

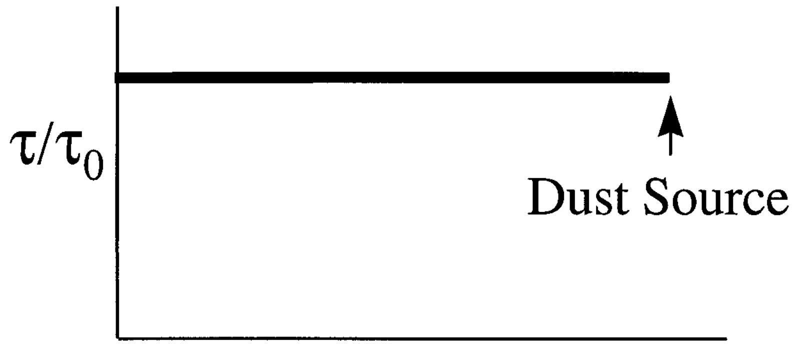
Disk geometry, either directly observed with high spatial resolution (H 4796A, ε Eri) or indirectly inferred from spectroscopy (β Pic), is subject to gravitational perturbations by any planets.

Giant planets

- Existence of planets within habitable zone linked to the formation & migration of giant planets within a primordial gas disk (Ward 1998; Gaidos 1999)
- Giant planets may also "protect" inner planets from an impact flux incompatible with the orgin and evolution of life.
- Presence is inferred from a "gap" or central "hole" in a debris disk.

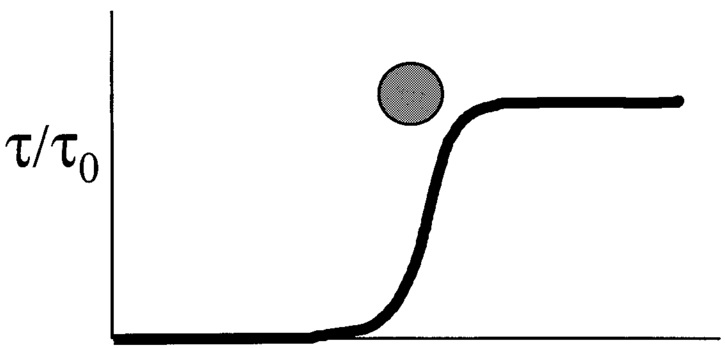
Kuiper-Edgewood Belt

- Scaling by dust production w.r.t. Solar System as indication of Kuiper belt mass and thus initial condensible mass surface density.
- Mass of nebula is a key parameter of solar system formation models.



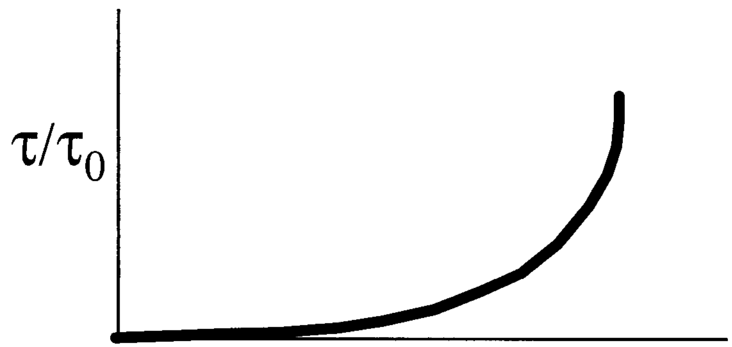
<u>Collisionless Disk</u>

$\tau/\tau_0 = 1$



<u>Disk with Clearing</u>

$\tau/\tau_0 = H(a-a_p)$



<u>Collisional Disk</u>

$\tau/\tau_0 = [1 + 2\tau_0 c(1-(a/a_0)^{1/2})]^{-1}$

$c = t_{pr}/t_{orb}$

<u>The Baroque (Model) Era</u>

Grain mineralogy → Planetary chemistry → Biological potential

Dust in a debris disk arises ***in part*** *from the disintegration of larger, long-lived bodies that have undergone geochemical processing important to the early chemical history and biological potential of planets.*

H_2O ice/hydrated SiO_2

- Theories suggest control of giant (and terrestrial?) planet formation
- Evacuation of water from inner planetary controls redox state of primordial nebula
- Water necessary for plate tectonics, climate control, biology

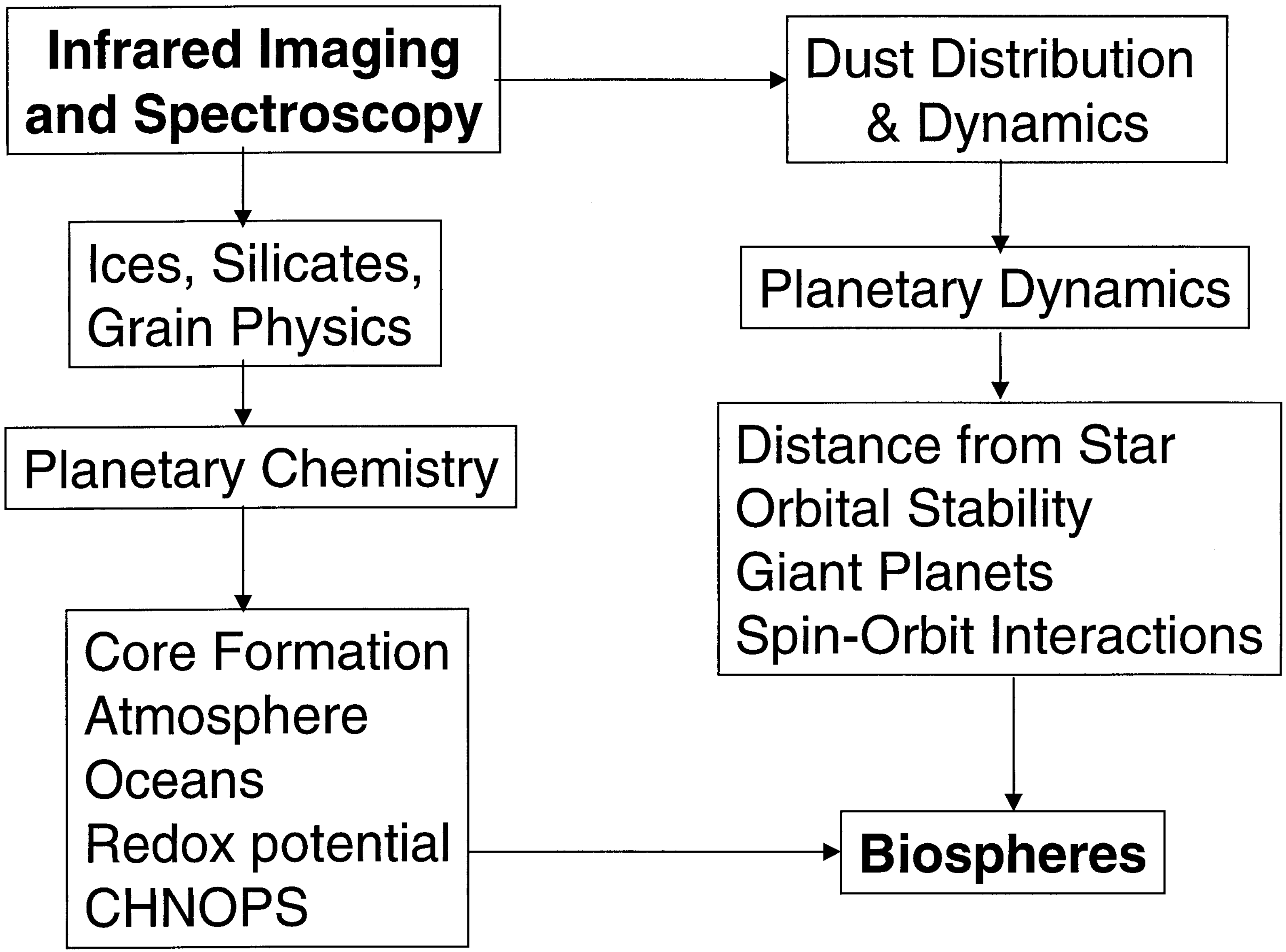
Fe^0/FeO

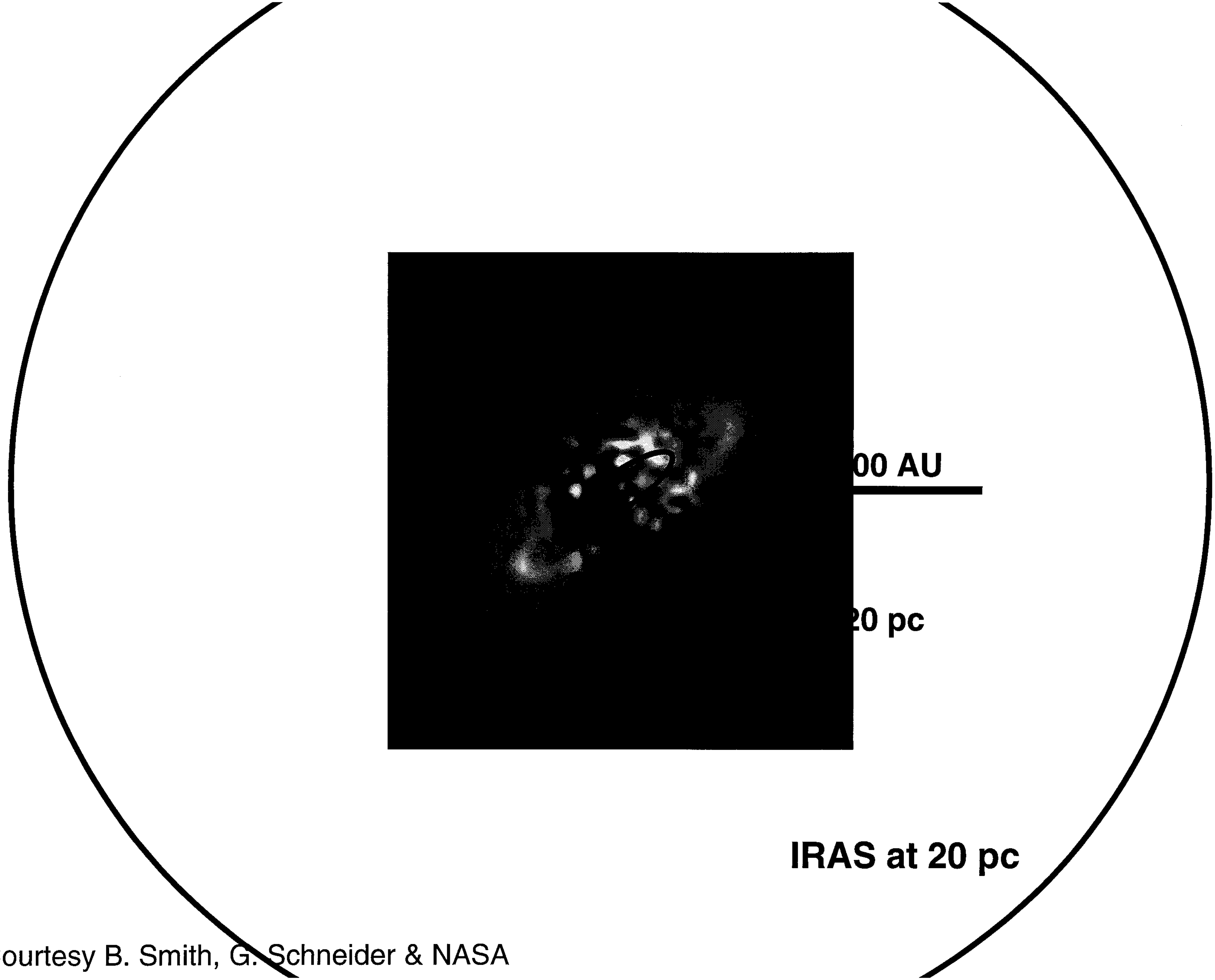
- Core formation and sequestration of siderophilic/lithophilic elements
- Thermal budget/history of bodies
- Global magnetic field capable of protecting volatiles from erosion
- Oxidation of Fe^0 is the primary chemical sink for H_2O

FeO Content and Infrared Spectroscopy Silicates

Olivines ($Mg_{2x-2}Fe_{2x}SiO_4$) Pyroxenes ($Mg_{x-1}Fe_xSiO_3$)

Fig. 7 of Jager et al. Astron. Astrophys 339: 904 (1998)


Infrared Imaging and Spectroscopy
Dust Distribution & Dynamics
Ices, Silicates, Grain Physics
Planetary Dynamics
Planetary Chemistry
Distance from Star
Orbital Stability
Giant Planets
Spin-Orbit Interactions
Core Formation
Atmosphere
Oceans
Redox potential
CHNOPS
Biospheres



Courtesy B. Smith, G. Schneider & NASA

Circumstellar Environment of Young Solar-Type Stars

- Dust and impact environment of young (life-forming?) planets.
- Impacts may frustrate or futher origin of life by sterilization or delivery of volatiles & organics.
- Gaidos (1999) using *IRAS* data found 1 of 38 young solar analogs (G and K) to have an infrared excess at 12/25 μm.
- Habing *et al*. (1999) report all stars younger than 300-400 Myr have an *ISO*-measured excess at 60 μm.